

6 APPENDICES

Appendix I: About USGCRP

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

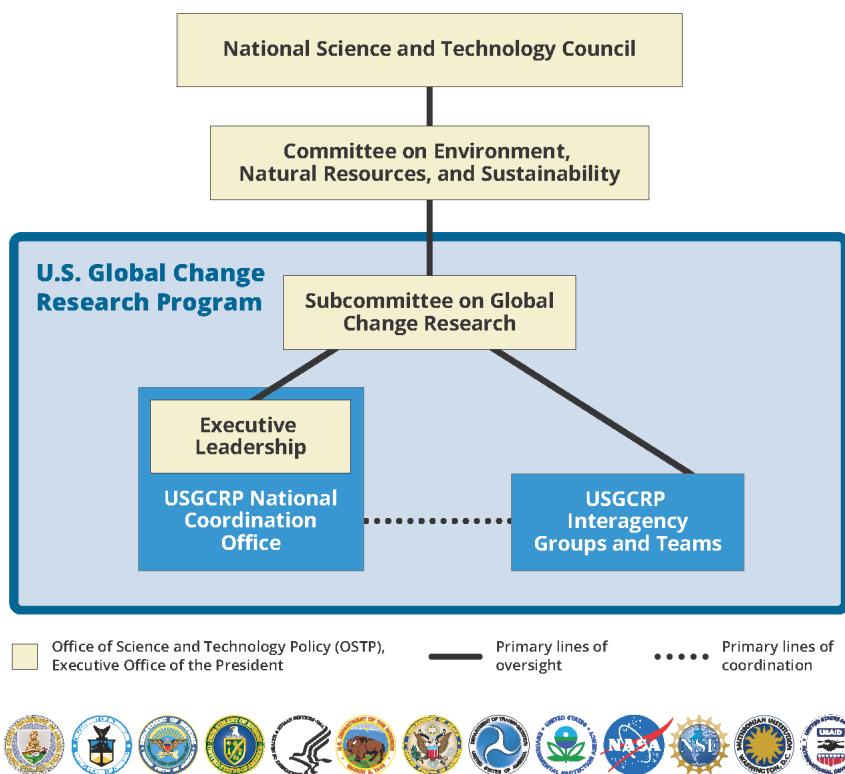
USGCRP coordinates and integrates global-change research across 13 Federal agencies (*see Figure 1: USGCRP Member Agencies*) to most effectively and efficiently serve the Nation and the world. Through interagency partnerships and collaborations with leading experts, USGCRP advances climate science and improves understanding of how global change is impacting society, both today and into the future.

As mandated by Congress, USGCRP develops a new strategic research plan every ten years, with triennial revisions and updates. The 2012–2021 Strategic Plan is being implemented by the collective efforts of USGCRP’s 13 member agencies. The goals laid out in the 2012–2021 Strategic Plan are to advance science, inform decisions, conduct sustained assessments, and communicate and educate through an integrated, end-to-end program.

The Program is directed and overseen by the [Subcommittee on Global Change Research](#) (SGCR), which is chartered under the [Committee on Environment, Natural Resources and Sustainability](#) (CENRS), a part of the [National Science and Technology Council](#) (NSTC). The SGCR oversees interagency activities through

the interagency working groups (IWGs) and the USGCRP National Coordination Office (*Figure 4: USGCRP Lines of Oversight and Coordination*).

Figure 4:
USGCRP Lines of Oversight and Coordination



IWGs are the primary USGCRP vehicles for implementing and coordinating global-change research activities within and across agencies. These groups are critical to integrating and assessing progress throughout the Program. The IWGs span a wide range of interconnected climate and global-change issues and address major components of the Earth’s environmental and human systems, as well as cross-disciplinary approaches for addressing these issues.

IWGs are designed to bring agencies together to plan, develop, and implement coordinated activities, and to identify

and fill gaps in the Program's plans. They allow public officials to communicate with each other on emerging directions within their agencies, their stakeholder needs, and best practices learned from agency activities. Together, these functions allow the agencies to work in a more coordinated and effective manner.

USGCRP's current working groups are the following:

- Adaptation Science Interagency Working Group
- Carbon Cycle Interagency Working Group
- Coordinating Group on Scenarios and Interpretative Science
- Education Interagency Working Group
- Global Change Information Interagency Working Group
- International Activities Interagency Working Group
- Interagency Crosscutting Group on Climate Change and Human Health
- Interagency Group on Integrative Modeling
- Interagency National Climate Assessment Working Group
- Integrated Observations Interagency Working Group
- Interagency Working Group on Indicators
- Process Research Coordinating Committee, including the following thematic clusters:
 - nitrogen cycle
 - biodiversity and ecosystems
 - clouds, chemistry, and aerosol processes
 - terrestrial water cycle and land-atmosphere interactions
- Social Sciences Coordinating Committee

Appendix II: USGCRP Member Agencies

This section summarizes the principal focus areas related to global-change research for each USGCRP member agency.

Department of Agriculture

The U.S. Department of Agriculture's (USDA's) Climate Change Research Program empowers land managers, policy makers, and its agencies with science-based knowledge to manage the risks and opportunities posed by climate change, reduce greenhouse gas emissions, and enhance carbon sequestration. USDA's Climate Change Research Program includes contributions from the Agricultural Research Service (ARS), the National Institute of Food and Agriculture (NIFA), the Forest Service (USDA-FS), Natural Resources Conservation Service (NRCS), National Agricultural Statistics Service (NASS), and Economic Research Service (ERS). In addition to these agencies, programmatic and operational support for adaptation preparedness and resilience, greenhouse gas mitigation, and outreach and education are contributed by the Risk Management Agency (RMA) and Rural Development (RD), the Animal and Plant Health Inspection Service (APHIS), the Farm Service Agency (FSA), the Office of the Chief Economist (OCE), and Departmental Management Offices (DM). USDA has established Regional Climate Hubs for Risk Adaptation and Mitigation. Together the many USDA research and programmatic entities help ensure sustained food security for the Nation and the World. They maintain and enhance the health of U.S. forests, rangelands and natural resources while identifying ways to manage the risks and vulnerabilities ranging from temperature and precipitation extremes to the changing biology of pests, invasive species, increased wildfire intensity and extent, and diseases.

USDA develops greenhouse gas inventories and conducts assessments and projections of climate-change impacts on the natural and economic systems associated with agricultural production and forest and forest products. USDA also develops cultivars, cropping systems, and management practices to improve drought tolerance and build resilience to climate variability. The USDA Building Blocks for Climate Smart Agriculture and Forestry framework spans a range of technologies and conservation practices to reduce greenhouse gas emissions, increase carbon storage, and generate renewable energy. USDA both conducts research and promotes integration of USGCRP research findings into farm and natural resource management, and helps build resiliency to climate change by developing and deploying decision support through its Regional Climate Hubs network and delivers science-based region-specific information and technology. USDA maintains critical long-term data collection and observation networks, including the Long-Term Agro-ecosystem Research (LTAR) Network, the Snowpack Telemetry (SNOTEL) network, the Soil Climate Analysis Network (SCAN), the National Resources Inventory (NRI), and the Forest Inventory and Analysis (FIA). Finally, USDA engages in communication, outreach, and education through multiple forums, including its vast network of agricultural extension services, its field offices, and its Regional Climate Hubs.

Department of Commerce

The National Oceanic and Atmospheric Administration (NOAA) and the National Institute of Standards and Technology (NIST) comprise the Department of Commerce's (DOC's) participation in USGCRP.

NOAA's strategic climate goal is "an informed society anticipating and responding to climate and its impacts."

NOAA's overall objective is to provide decision makers with a predictive understanding of the climate and to communicate climate information so that people can make more informed decisions in their lives, businesses, and communities. These outcomes are pursued by implementing a global observing system, conducting research to understand climate processes, developing improved modeling capabilities, and developing and deploying climate educational programs and information services. NOAA aims to achieve its climate goal through the following strategic objectives:

- Improved scientific understanding of the changing climate system and its impacts
- Assessments of current and future states of the climate system that identify potential impacts and inform science, service, and stewardship decisions
- Mitigation and adaptation efforts supported by sustained, reliable, and timely climate services
- A climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions.

NIST works with other Federal agencies to develop or extend internationally accepted traceable measurement standards, methodologies, and technologies that enhance measurement capabilities for greenhouse gas emission inventories and measurements critical to advancing climate science research. NIST provides measurements and standards that support accurate, comparable, and reliable climate observations and provides calibrations and special tests to improve the accuracy of a wide range of instruments and techniques used in climate research and monitoring.

Department of Defense

The Department of Defense (DOD)—while not supporting a formal mission dedicated to global change research—is developing policies and plans to manage and respond to the effects of climate change on DOD missions, assets, and the operational environment. Various research agencies within DOD sponsor and undertake basic research activities that concurrently satisfy both national security requirements as well as the strategic goals of USGCRP. These include the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Defense Advanced Research Projects Agency (DARPA). When applicable, the research activities of these agencies are coordinated with other Federally sponsored research via USGCRP and other entities.

Because the performance of DOD systems and platforms are influenced by environmental conditions, understanding the variability of the Earth's environment and the potential for change is of great interest to the Department. DOD is responsible for the environmental stewardship of hundreds of installations throughout the U.S., and must continue incorporating geostrategic and operational energy considerations into force planning, requirements development, and acquisition processes. DOD relies on the Strategic Environmental Research and Development Program (SERDP), a joint effort among DOD, DOE, and EPA, to develop climate-change assessment tools and to identify the environmental variables that must be forecast with sufficient lead time to facilitate appropriate adaptive responses. Each service agency within DOD incorporates the potential impact of global change into their long-range strategic plans. For example, the Navy's Task Force Climate Change (TFCC) assists in the development of science-based recommendations, plans, and actions to adapt to climate change. The USACE Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL) also actively investigates the impacts of climate trends for DOD and other agencies. The CRREL

research program responds to the needs of the military, but much of the research also benefits the civilian sector and is funded by non-military customers such as NSF, NOAA, NASA, DOE, and state governments.

Department of Energy

The Department of Energy's (DOE) Office of Science supports fundamental research to understand the energy-environment-climate connection and its implications for energy production, use, sustainability, and security—with particular emphasis on the potential impact of increased anthropogenic emissions. The ultimate goal is to advance a robust predictive understanding of Earth's climate and environmental systems and to inform the development of sustainable solutions to the Nation's energy and environmental challenges.

Two DOE research areas focus on areas of uncertainty in Earth systems models: Atmospheric System Research (science of aerosols, clouds, and radiative transfer); and Terrestrial Ecosystem Science (role of terrestrial ecosystems and carbon cycle observations). DOE also collaborates with NSF to develop the widely used Community Earth System Model, supports methods to obtain regional climate information, integrates analysis of climate-change impacts, and analyzes and distributes large climate datasets through the Program for Climate Model Diagnosis and Intercomparison and the Earth System Grid. The Department also supports the ARM Climate Research Facility, a scientific user facility that provides the research community with unmatched measurements permitting the most detailed high-resolution, three-dimensional documentation of evolving cloud, aerosol, and precipitation characteristics in climate sensitive sites around the world.

Finally, DOE also conducts applied climate-related research, which is centered in DOE's Office of Energy Policy and Systems Analysis and Office of Policy and International Affairs. These programs develop and utilizes energy-economic models, including integrated assessment models, to evaluate policies and programs that enable cost-effective greenhouse gas reductions and accelerate the development and deployment of clean energy technologies. This includes supporting work to characterize climate-change impacts for use in policy analysis, vulnerability, and adaptation assessment and agency rulemakings. DOE also conducts assessments of climate change on electric grid stability, water availability for energy production, and site selection of the next generation of renewable energy infrastructure.

Department of Health and Human Services

The U.S. Department of Health and Human Services (HHS) supports a broad portfolio of research and decision support initiatives related to environmental health and the health effects of global climate change, primarily through the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC). Research focuses on the need to better understand the vulnerabilities of individuals and communities to climate-related changes in health risks such as heat-related morbidity and mortality, respiratory effects of altered air contaminants, changes in transmission of infectious diseases, and impacts in the aftermath of severe weather events, among many others. Research efforts also seek to assess the effectiveness of various public-health adaptation strategies to reduce climate vulnerability, as well as the potential health effects of interventions to reduce greenhouse gas emissions.

Specifically, HHS supports USGCRP by conducting fundamental and applied research on linkages between climate change and health, translating scientific advances into decision support tools for public-health professionals, conducting ongoing monitoring and surveillance of climate-related health outcomes, and engaging

the public-health community in two-way communication about climate change.

Department of the Interior

The U.S. Geological Survey (USGS) conducts global change research for the Department of the Interior (DOI) and constitutes DOI's formal participation in USGCRP.

USGS scientists work with other agencies to provide policy makers and resource managers with scientifically valid information and predictive understanding of global change and its effects with the ultimate goal of helping the Nation understand, adapt to, and mitigate global change.

Specifically, the USGS Climate and Land Use Change Research and Development Program supports research to understand processes controlling Earth system responses to global change and model impacts of climate and land-cover change on natural resources. The USGS Land Change Science and Land Remote Sensing programs (such as the Landsat satellite mission and the National Land Cover Database) provide data that is used to assess changes in land use, land cover, ecosystems, and water resources resulting from the interactions between human activities and natural systems. The science products and datasets from these programs are essential for DOI's biological carbon sequestration project (LandCarbon), which is conducting quantitative studies of carbon storage and greenhouse gas flux in the Nation's ecosystems.

USGS also leads the regional DOI Climate Science Centers (CSCs) that provide science and technical support to other bureaus as well as region-based partners, such as Landscape Conservation Cooperatives (LCCs), that are dealing with the impacts of climate change on fish, wildlife, and ecological processes. The LCCs complement and work closely with the CSCs, focusing on convening partners, developing shared plans, and delivering applied tools for addressing climate change and other landscape-scale stressors.

Department of State

Through the Department of State (DOS) annual funding, the U.S. is the world's leading financial contributor to the United Nations Framework Convention on Climate Change (UNFCCC) and to the IPCC—the principal international organization for the assessment of scientific, technical, and socioeconomic information relevant to the understanding of climate change, its potential impacts, and options for adaptation and mitigation. Recent DOS contributions to these organizations provide substantial support for global climate observation and assessment activities in developing countries. DOS also works with other agencies in promoting international cooperation in a range of bilateral and multilateral climate-change initiatives and partnerships.

Department of Transportation

The Department of Transportation (DOT) conducts research to examine potential climate-change impacts on transportation, methods for increasing transportation efficiency, and methods for reducing emissions that contribute to climate change. DOT's Center for Climate Change and Environmental Forecasting coordinates transportation and climate-change research, policies, and actions within DOT and promotes comprehensive approaches to reduce emissions, address climate-change impacts, and develop adaptation strategies. DOT also contributes directly to USGCRP's National Climate Assessment through focused research such as the Center's

Gulf Coast Studies. The Gulf Coast Phase 2 study, completed in FY 2015, developed tools to assist transportation agencies in performing climate change and extreme weather vulnerability assessments and build resilience.

The Federal Aviation Administration (FAA) works closely with USGCRP and its participating agencies to identify and address key scientific gaps regarding aviation climate impacts and to inform mitigation solutions. Other DOT initiatives to address climate change and improve the sustainability of the U.S. transportation sector follow:

The Federal Highway Administration (FHWA) and other DOT agencies are undertaking climate impact and adaptation studies (including vulnerability and risk assessments), working with science agencies to develop regional climate data and projections, conducting methodological research, supporting pilot programs, and providing assistance to transportation stakeholders including state, metropolitan, and local agencies. DOT has requested funding in FY 2017 for these purposes. The Federal Transit Administration (FTA) completed seven Climate Change Adaptation Pilot studies to advance the state of the practice in adapting transit assets and operations to the impacts of climate change. These tools will help transportation agencies to consider improved resiliency and reliability of the transportation system in transportation planning, asset management and project development.

The FAA manages the Continuous Lower Energy, Emissions, and Noise (CLEEN) program as a government–industry consortium to develop technologies for energy efficiency, noise and emissions reduction, and sustainable alternative jet fuel. FAA also participates in the Commercial Aviation Alternative Fuels Initiative (CAAIFI), a public–private coalition to encourage the development of sustainable alternative jet fuel.

Environmental Protection Agency

The core purpose of the Environmental Protection Agency's (EPA's) global-change research program is to develop scientific information that supports policy makers, stakeholders, and society at large as they respond to climate change and associated impacts on human health, ecosystems, and socioeconomic systems. EPA's research is driven by the Agency's mission and statutory requirements, and includes: (1) improving scientific understanding of global change effects on air quality, water quality, ecosystems, and human health in the context of other stressors; (2) assessing and defining adaptation options to effectively prepare for and respond to global change risks, increase resilience of human and natural systems, and promote their sustainability; and (3) developing an understanding of the potential environmental and human health impacts of greenhouse gas emissions reduction technologies and approaches to inform mitigation solutions. EPA Program Offices and Regions leverage this research to support mitigation and adaptation decisions and to inform communication with external stakeholders and the public.

EPA relies on USGCRP to develop high-quality scientific models, data, and assessments to advance understanding about physical, chemical, and biological changes to the global environment and their relation to drivers of global climate change. Satellite and other observational efforts conducted by USGCRP agencies are crucial to supporting EPA's efforts to understand how land-use change, population change, climate change, and other global changes are affecting ecosystems, and the services they provide. EPA's global-change research applies and extends these results using regional and local air quality, hydrology, and sea-level rise models to better understand the impacts of climate change to specific human health and ecosystem endpoints in ways that enable local, regional, and national decision makers to develop and implement strategies to protect human

health and the environment. In turn, EPA's research provides USGCRP agencies with information and understanding about the connections between global change and impacts at local, regional, and national scales, as well as how mitigation and adaptation actions may influence global changes.

EPA's research informs approaches to prepare for, adapt to, and minimize the impacts of climate change, including extreme weather events, wildfire, and rising sea levels, and their impacts on human health and well-being and social and economic systems. Other EPA program activities include the development and application of economic and biophysical models to generate projections of potential future greenhouse gas emissions trajectories and mitigation scenarios. EPA also applies long-term datasets and analytical tools to communicate observed climate change indicators and conduct economic and risk modeling to examine and project impacts and economic damages associated with global mitigation scenarios. EPA collaborates with other agencies and numerous stakeholders to develop the Inventory of U.S. Greenhouse Gas Emissions and Sinks, which is submitted to the United Nations in accordance with the Framework Convention on Climate Change. Lastly, EPA efforts include technical evaluation of biogenic emissions fluxes associated with biomass use for energy.

National Aeronautics and Space Administration

NASA's global change activities have four integrated foci: satellite observations, research and analysis, applications, and technology development. Satellites provide critical global atmosphere, ocean, land, sea ice, and ecosystem measurements. NASA's 22 on-orbit satellite missions (as of July 2016) measure numerous variables required to enhance understanding of Earth interactions. NASA is now routinely providing data from satellites launched in the 12-month period from February 2014 to January 2015: including precipitation data from the Global Precipitation Measurement (GPM), carbon dioxide data from the Orbiting Carbon Observatory-2 (OCO-2), and soil moisture data from the Soil Moisture Active Passive (SMAP), as well as wind and aerosol/cloud data from two payloads aboard the International Space Station (ISS), RapidScat and Cloud-Aerosol Transport System, respectively. NASA is also contributing to ocean and atmosphere observations with satellites launched by interagency partners (Jason-3, Deep Space Climate Observatory). NASA has delivered two payloads for planned late 2016 launch to the ISS: the Lightning Imaging Sensor, and the Stratospheric Aerosol and Gas Experiment-III. In November 2016, NASA will launch the Cyclone Global Navigation Satellite System constellation of eight nanosatellites to study winds associated with tropical storms and severe weather systems. In 2016, NASA selected two additional satellite missions as part of its Earth Venture-Instrument series of missions: 1) the Multi-Angle Imager for Aerosols, which will provide observations of small atmospheric aerosol particles to be combined with health information to determine the toxicity of different particulate matter types in airborne pollutants over the world's major cities; and 2) Time-Resolved Observations of Precipitation structure and storm intensity with a Constellation of Smallsats, which will develop and launch a constellation of CubeSats to study the development of tropical cyclones through rapid-revisit sampling.

The Administration's FY 2017 budget also enables NASA to continue its program in sustainable land imaging (in coordination with the U.S. Geological Survey) and in long-term monitoring responsibility for environmental parameters not directly in support of weather forecasting, such as solar radiation, Earth radiation budget, ozone vertical profile, and sea-surface height.

NASA's program advances observing technology and leads to new and enhanced space-based observation and information systems. The Earth science research program explores interactions among the major components of the Earth system—continents, oceans, atmosphere, ice, and life—to distinguish natural from human-in-

duced causes of change and to understand and predict the consequences of change. NASA makes significant investments to assure the quality and integration of data through calibration and validation efforts that include satellite, surface, and airborne measurements, as well as data intercomparisons. NASA also carries out observationally driven modeling projects that include data assimilation, reanalysis, process representation, initialization, and verification. Six significant new multi-year airborne campaigns initiated in 2015 began deployment in 2016. They address major global environmental issues: sources and sinks of atmospheric carbon in the continental United States; the role of the ocean in melting of ice sheets at the coast of Greenland; the effects of biomass burning in Africa on cloud structure off its western coast; the latitudinal variation of radiatively- and chemically-active trace constituents in the upper troposphere over the Atlantic and Pacific oceans; and the seasonal variation of biological productivity in the North Atlantic ocean and its implications for the overlying atmosphere. Applications projects extend the societal benefits of NASA's research, technology, and spaceflight programs to the broader U.S. public through the development and transition of user-defined tools for decision support, and are focused on such areas as water resources, health/air quality, and ecological forecasting. The Earth science technology program enables previously infeasible science investigations, improves existing measurement capabilities, and reduces the cost, risk, and/or development times for Earth science instruments. During the FY 2016/FY 2017 timeframe it will launch several small satellites as part of its InSpace Validation of Earth Science Technologies.

National Science Foundation

The National Science Foundation (NSF) addresses global-change issues through investments that advance frontiers of knowledge, provide state-of-the-art instrumentation and facilities, develop new analytical methods, and enable cross-disciplinary collaborations while also cultivating a diverse, highly trained workforce and developing educational resources. In particular, NSF global-change programs support the research and related activities to advance fundamental understanding of physical, chemical, biological, and human systems and the interactions among them. The programs encourage interdisciplinary approaches to studying Earth system processes and the consequences of change, including how humans respond to changing environments and the impacts on ecosystems and the essential services they provide. NSF programs promote the development and enhancement of models to improve understanding of integrated Earth system processes and to advance predictive capability. NSF also supports fundamental research on the processes used by organizations and decision makers to identify and evaluate policies for mitigation, adaptation, and other responses to the challenge of a changing and variable environment. Long-term, continuous, and consistent observational records are essential for testing hypotheses quantitatively and are thus a cornerstone of global-change research. NSF supports a variety of research observing networks that complement, and are dependent on, the climate monitoring systems maintained by its sister agencies.

NSF regularly collaborates with other USGCRP agencies to provide support for a range of multi-disciplinary research projects and is actively engaged in a number of international partnerships.

Smithsonian Institution

Within the Smithsonian Institution (SI), global-change research is primarily conducted at the National Air and Space Museum, the National Museum of Natural History, the National Zoological Park, the Smithsonian Astrophysical Observatory, the Smithsonian Environmental Research Center, and the Smithsonian Tropical Research Institute. Research is organized around themes of atmospheric processes, ecosystem dynamics,

observing natural and anthropogenic environmental change on multiple time scales, and defining longer-term climate proxies present in the historical artifacts and records of the museums as well as in the geologic record. Most of these units participate in the Smithsonian's Global Earth Observatories, examining the dynamics of forests (ForestGEO, formerly SIGEO) and coastal marine habitats (MarineGEO) over decadal time frames.

The Smithsonian Grand Challenge for Understanding and Sustaining a Biodiverse Planet brings together researchers from around the Institution to focus on joint programs ranging from estimating volcanic emissions to ocean acidification measurement. Smithsonian paleontological research documents and interprets the history of terrestrial and marine ecosystems from 400 million years ago to the present. Other scientists study the impacts of historical environmental change on the ecology and evolution of organisms, including humans. Archaeobiologists examine the impact of early humans resulting from their domestication of plants and animals, creating the initial human impacts on planetary ecosystems.

These activities are joined by related efforts in the areas of history and art, such as the Center for Folklife and Cultural History, the National Museum of the American Indian, and the Cooper Hewitt, Smithsonian Design Museum to examine human responses to global change, within communities, reflected in art and culture, food, and music. Finally, Smithsonian outreach and education expands our scientific and social understanding of processes of change and represents them in exhibits and programs, including at the history and art museums of the Smithsonian. USGCRP funding enables the Smithsonian to leverage private funds for additional research and education programs on these topics.

U.S. Agency for International Development

The U.S. Agency for International Development (USAID) supports programs that enable decision makers to apply high-quality climate information to decision making. USAID's climate-change and development strategy calls for enabling countries to accelerate their transition to climate resilient, low emission sustainable economic development through direct programming and integrating climate-change adaptation and mitigation objectives across the Agency's development portfolio. USAID is the lead contributor to bilateral assistance, with a focus on capacity building, civil society building, and governance programming, and creating the legal and regulatory environments needed to address climate change. USAID leverages scientific and technical resources from across the U.S. Government (for example, NASA, NOAA, USDA, USGS) as it applies its significant technical expertise to provide leadership in development and implementation of low-emissions development strategies, creating policy frameworks for market-based approaches to emission reduction and energy sector reform, promoting sustainable management of agriculture lands and forests, and mainstreaming adaptation into development activities in countries most at risk. USAID has long-standing relationships with host country governments that enable them to work together to develop shared priorities and implementation plans. USAID's engagement and expertise in agriculture, biodiversity, infrastructure, and other critical climate sensitive sectors provide an opportunity to implement innovative cross-sectoral climate-change programs. Finally, USAID bilateral programs work in key political and governance areas where multilateral agencies cannot.

Appendix III: Observations to Support Global-Change Research

USGRP science—including fundamental research, modeling, assessments, and science for decision support—has its foundation in sustained and experimental observations of Earth’s atmosphere, oceans, ice, land, and ecosystems. USGCRP’s portfolio of Earth observations includes satellite, airborne, ground-based, and ocean-based missions, platforms, and networks—all of which provide measurements necessary for understanding and responding to global change. As an illustration of the breadth and depth of the Program’s observational capabilities, this table lists examples of observational efforts that have begun or will begin and those that have ended or will end in 2015 or 2016. It does not include existing longer-term observations systems.

A. Projects completed in 2015 or 2016

<i>Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) Experiment</i>	<p>Description: AirMOSS collects and uses airborne radar to collect soil moisture data from nine climatic habitats in North America to estimate how much carbon the continent is taking in or releasing to the atmosphere.</p> <p>Sponsoring agencies: NASA (EVS-1)</p> <p>Observation type: field campaign</p> <p>Location: Continental United States and Alaska</p> <p>Timeline: March 2012 – August 2016</p> <p>More Information: https://airmoss.jpl.nasa.gov</p>
<i>Airborne Tropical Tropopause Experiment (ATTREX)</i>	<p>Description: ATTREX used measurements onboard the NASA Global Hawk to investigate: the role of stratospheric water vapor in Earth’s energy budget and climate; dehydration of tropospheric air entering the stratosphere; and the physical processes and chemical composition of the Tropical Tropopause Layer (TTL) to better understand the controls on the composition of the stratosphere.</p> <p>Sponsoring agencies: NASA (EVS-1)</p> <p>Observation type: field campaign</p> <p>Location: Flights from Palmdale, CA (Oct-Nov 2011, Jan-Feb 2013, Feb-Mar 2015) and Guam (Jan-Mar 2014)</p> <p>Timeline: November 2011 – November 2015</p> <p>More Information: https://espo.nasa.gov/missions/attrex</p>
<i>Aquarius</i>	<p>Description: Aquarius was a focused satellite mission to measure sea surface salinity that provided the global view of salinity variability needed for climate studies.</p> <p>Sponsoring agencies: NASA, CONAE (Argentina)</p> <p>Observation type: satellite</p> <p>Location: global</p> <p>Timeline: June 2011 to June 2015.</p> <p>More Information: http://aquarius.nasa.gov/</p>
<i>Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)</i>	<p>Description: CARVE is a five-year mission to measure carbon dioxide and methane fluxes from Alaska, using sensors aboard a NASA aircraft to deliver the first simultaneous measurements of surface parameters that control gas emissions and total atmospheric columns of carbon dioxide, methane, and carbon monoxide. Continuous ground-based measurements provide temporal and regional context as well as calibration for airborne measurements. Contributions of tower and aircraft observations were provided by NOAA as well as a tower near Fairbanks with continuous measurements of methane.</p> <p>Sponsoring agencies: NASA (EVS-1), NOAA</p> <p>Observation type: field campaign</p> <p>Location: Alaska</p> <p>Timeline: November 2010 – November 2015</p> <p>More information: http://science.nasa.gov/missions/carve/</p>

<p>Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ)</p>	<p>Description: DISCOVER-AQ is a five-year mission to improve the interpretation of satellite observations to diagnose near-surface conditions relating to air quality. This campaign utilized an systematic and concurrent observation strategy which included: in situ vertical profiles on the NASA P-3B; remote sensing mapping of trace gas and aerosol columns on the UC-12; surface lidar and balloon soundings; and continuous monitoring of trace gases and aerosols at surface sites (including both in situ and column-integrated quantities).</p> <p>Sponsoring agencies: NASA (EVS-1)</p> <p>Observation type: field campaign</p> <p>Location: Baltimore-Washington (2011), Houston (2013), San Joaquin Valley (2013), Denver (2014)</p> <p>Timeline: November 2010 – November 2015</p> <p>More information: http://discover-aq.larc.nasa.gov</p>
<p>Hurricane and Severe Storm Sentinel (HS3)</p>	<p>Description: HS3 is a five-year mission specifically targeted to investigate the processes that underlie hurricane formation and intensity change in the Atlantic Ocean basin. HS3 is motivated by hypotheses related to the relative roles of the large-scale environment and storm-scale internal processes. HS3 addresses the role of the Saharan Air Layer in tropical storm formation and intensification as well as the role of deep convection in the inner-core region of storms.</p> <p>Sponsoring agencies: NASA (EVS-1)</p> <p>Observation type: field campaign</p> <p>Location: 2011 (Pacific Atm River), 2012 (Hurr. Leslie, TS and Hurr Nadine), 2013 (Ex-TS Erin, TS Gabrielle, Hurr. Ingrid, TS Humberto), 2014 (Hurr. Cristobal, TS Dolly, TS and Hurr. Edouard, Hurr. Gonzalo)</p> <p>Timeline: November 2010 – November 2015</p> <p>More information: https://espo.nasa.gov/hs3/</p>
<p>Tropical Rainfall Measurement Mission (TRMM)</p>	<p>Description: TRMM studied rainfall for weather and climate research. It delivered a unique 17-year dataset of global tropical rainfall and lightning. The TRMM dataset became the space standard for measuring precipitation, and led to research that improved understanding of tropical cyclone structure and evolution, convective system properties, lightning-storm relationships, climate and weather modeling, and human impacts on rainfall.</p> <p>Sponsoring Agencies: NASA, JAXA</p> <p>Observation type: satellite</p> <p>Location: Global tropics (32°N to 32°S).</p> <p>Timeline: November 1997 to April 2016.</p> <p>More information: http://trmm.gsfc.nasa.gov/</p>
<p>Twin Otter Projects Defining Oil/gas Well emissionS (TOPDOWN)</p>	<p>Description: TOPDOWN aims to understand the atmospheric impact of rapidly expanding oil and gas operations in the Bakken play in North Dakota through downwind cross-section flights of the active field, quantifying key atmospheric trace gases (carbon dioxide, carbon monoxide, methane, ethane, ozone, and more), and black carbon using airborne in situ sensors and complementary airborne remote sensing instrumentation. Subsequent flights examined the Denver-Julesburg basin in northeast Colorado, and the San Juan basin in New Mexico.</p> <p>Sponsoring agencies: NOAA, NASA, NSF, DOE</p> <p>Observation type: field campaign</p> <p>Location: North Dakota, Colorado, New Mexico, United States</p> <p>Timeline: May–June 2014, April 2015</p> <p>More information: http://www.esrl.noaa.gov/csd/groups/csd7/measurements/2014topdown/</p>
<p>Solar Forecast Improvement Project (SFIP)</p>	<p>Description: two mobile Surface Radiation Network (SURFRAD) platforms were deployed in support of SFIP. Scientific goals are: model verification using SURFRAD and Integrated Surface Irradiance Study (ISIS) site measurements, provision of high-quality solar radiation measurements for 14 ISIS and SURFRAD sites, analysis of this data for comparison to satellite and model products, and high quality diffuse and direct solar irradiance.</p> <p>Sponsoring agencies: NOAA, DOE</p> <p>Observation type: field campaign</p> <p>Location: Vermont, Colorado</p> <p>Timeline: Vermont (October 2014–~October 2015); Colorado (July 2014–~December 2015)</p> <p>More information: http://www.esrl.noaa.gov/gmd/grad/surfrad/; http://www.esrl.noaa.gov/gmd/grad/isis/; http://energy.gov/eere/sunshot/solar-forecast-improvement-project</p>

B. Projects initiated in 2015 or 2016

Arctic-Boreal Vulnerability Experiment (ABOVE)	<p>Description: ABOVE is a large-scale investigation of the impact of environmental change on ecosystem function, ecosystem services, and its implications for social-ecological systems in Alaska and northwestern Canada. ABOVE research links field-based, process-level studies with geospatial data products derived from airborne and satellite sensors, providing a foundation for improving analysis and modeling capabilities for northern ecosystems.</p> <p>Sponsoring agencies: NASA in partnership with DOE, DOI, US Forest Service, State of Alaska as well as several federal and provincial agencies in Canada.</p> <p>Observation type: field campaign</p> <p>Location: Alaska and western Canada</p> <p>Timeline: September, 2015 – September 2023</p> <p>More information: http://above.nasa.gov/index.html</p>
Atmospheric Radiation Measurement (ARM) Cloud Aerosol Precipitation Experiment (ACAPEX)/CalWater2	<p>Description: ACAPEX/CalWater2 is a joint campaign to improve understanding and modeling of large-scale dynamics and cloud and precipitation processes associated with atmospheric rivers and aerosol-cloud interactions that influence precipitation variability and extremes in the western United States.</p> <p>Sponsoring agencies: NOAA, DOE, NASA</p> <p>Observation type: field campaign</p> <p>Location: western United States</p> <p>Timeline: January–May 2015</p> <p>More information: ACAPEX: http://www.arm.gov/sites/amf/acx CalWater2: http://www.esrl.noaa.gov/psd/calwater/overview/</p>
Atmospheric Carbon and Transport (ACT-America)	<p>Description: ACT-America involves five six-week airborne campaigns to quantify anomalies in atmospheric carbon. The campaign will enable and demonstrate a new generation of atmospheric inversion systems for quantifying carbon dioxide and methane sources and sinks.</p> <p>Sponsoring agencies: NASA (EVS-2), NOAA</p> <p>Observation type: field campaign</p> <p>Location: Eastern United States</p> <p>Timeline: July 2016 – May 2018 (est.)</p> <p>More information: http://act-america.larc.nasa.gov</p>
ARM Airborne Carbon Measurements (ACME)	<p>Description: ACME conducts airborne observations and analysis of atmospheric trace gases, designed to improve fundamental understanding of the carbon cycle. The project coordinates with the NASA Carbon in Arctic Reservoirs Vulnerability Experiment campaign.</p> <p>Sponsoring agencies: DOE, NASA</p> <p>Observation type: field campaign</p> <p>Location: DOE Atmospheric Radiation Measurement Southern Great Plains (SGP) and North Slope of Alaska (NSA) sites</p> <p>Timeline: FY 2009 – FY 2016 (SGP); June – August 2015 (NSA)</p> <p>More information: https://www.arm.gov/campaigns/aaf2014armacmev</p>
Atmospheric Tomography Mission (ATom)	<p>Description: ATom is a global-scale aircraft sampling of the atmosphere to study the impact of air pollution on greenhouse gases and chemically-reactive gases in the atmosphere, to improve the representation of chemically-reactive gases and short-lived climate forcers in global models of atmospheric chemistry and climate. Profiles of the reactive gases will also provide critical information for validation of satellite data, particularly in remote areas where <i>in situ</i> data is lacking. Flights will occur in each of 4 seasons over a 4-year period.</p> <p>Sponsoring agencies: NASA (EVS-2)</p> <p>Observation type: field campaign</p> <p>Location: global</p> <p>Timeline: April 2015 – April 2019</p> <p>More information: http://science.nasa.gov/missions/atom/</p>

ARM West Antarctic Radiation Experiment (AWARE)	<p>Description: AWARE deploys the DOE Atmospheric Radiation Measurement Mobile Facility to Antarctica to study the role of clouds and aerosols on the surface energy budget in this rapidly warming region, and improve fundamental understanding of the surface energy budget, and the cloud and aerosol processes that impact it, in an under-observed region.</p> <p>Sponsoring agencies: NSF, DOE</p> <p>Observation type: field campaign</p> <p>Location: Antarctica</p> <p>Timeline: November 2015 – November 2016</p> <p>More information: http://www.arm.gov/campaigns/amf2015aware</p>
Airborne Visible-Infrared Imaging Spectrometer-Next Generation (AVIRIS-NG) - India	<p>Description: AVIRIS-NG was a three-month airborne campaign in India collecting imaging spectroscopy measurements for 57 sites.</p> <p>Sponsoring agencies: NASA, ISRO</p> <p>Observation type: field campaign</p> <p>Location: India</p> <p>Timeline: March-April 2016</p> <p>More information: http://aviris-ng.jpl.nasa.gov/</p>
Coral Reef Airborne Laboratory (CORAL)	<p>Description: CORAL will provide the most extensive picture to date of the condition of a large portion of the world's coral reefs from a uniform data set. CORAL acquires airborne spectral image data using the Portable Remote Imaging Spectrometer (PRISM) instrument.</p> <p>Sponsoring Agencies: NASA (EVS-2)</p> <p>Observation Type: field campaign</p> <p>Location: Hawaii (June 2016, Feb 2017), Great Barrier Reef (Sept-October 2016), April - May (Paulau and Mariana Islands)</p> <p>Timeline: June 2016 – December 2017</p> <p>More Information: http://airbornescience.jpl.nasa.gov/campaign/coral</p>
DamWatch	<p>Description: DamWatch is a tool to help watershed project sponsors monitor and manage dams that were built with assistance from USDA National Resources Conservation Service. It provides real-time monitoring of rainfall, snowmelt, stream flow, and seismic events that could pose potential threats to dam safety. In its first year of service, it has monitored 12,000 dams across the country.</p> <p>Sponsoring agencies: USDA</p> <p>Observation type: surface measurement network</p> <p>Location: United States</p> <p>Timeline: June 2015 – present</p> <p>More information: http://www.usengineeringsolutions.com/dam-watch/; http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/newsroom/releases/?cid=NRCSEPRD366417</p>
Earth Polychromatic Imaging Camera (EPIC)	<p>Description: EPIC is a 10-channel spectroradiometer (317 – 780 nm) onboard NOAA's DSCOVR (Deep Space Climate Observatory) spacecraft that provides 10 narrow band spectral images of the entire sunlit face of Earth. The DSCOVR spacecraft is located at the Earth-Sun Lagrange-1 (L-1) point giving EPIC a unique perspective that will be used in science applications to measure ozone, aerosols, cloud reflectivity, cloud height, vegetation properties, and UV radiation estimates at Earth's surface.</p> <p>Sponsoring agencies: NASA/NOAA</p> <p>Observation type: satellite</p> <p>Location: global</p> <p>Timeline: February 2015–present</p> <p>More information: http://epic.gsfc.nasa.gov</p>
Evaluation of Routine Measurements using Unmanned Aerial Systems (ERASMUS)	<p>Description: ERASMUS collects atmospheric measurements using a small unmanned aerial system, geared toward improved understanding of Arctic moisture and radiation budgets designed to complement those concurrently obtained by the third DOE ARM Mobile Facility. The second stage of ERASMUS in spring 2016 focused on aerosol measurements.</p> <p>Sponsoring agencies: DOE</p> <p>Observation type: field campaign</p> <p>Location: Alaska</p> <p>Timeline: August 2015 – April 2016</p> <p>More information: https://www.arm.gov/campaigns/amf2015erasmus</p>

<i>Hyperspectral Infrared Imager (HyspIRI) Airborne Campaign</i>	<p>Description: NASA is conducting preparatory airborne campaigns for the potential Hyperspectral Infrared Imager (HyspIRI) mission, using the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and the MODIS/ASTER Airborne Simulator (MASTER) instruments on a NASA ER-2 aircraft to collect precursor datasets in advance of the HyspIRI satellite observations, and demonstrate the science and applications research enabled by HyspIRI-type data (continuous spectral measurements in the visible to short-wavelength infrared).</p> <p>Sponsoring agencies: NASA</p> <p>Observation type: field campaign</p> <p>Location: California</p> <p>Timeline: 2013 – 2016</p> <p>More information: https://hyspiri.jpl.nasa.gov, http://aviris.jpl.nasa.gov, http://master.jpl.nasa.gov</p>
<i>KORUS-AQ/OC</i>	<p>Description: Joint field study between NASA and the Republic of Korea to assess air quality across urban, rural and coastal South Korea using observations from aircraft, ground sites, ships and satellites to test air quality models and remote sensing methods. Findings will help develop observing systems using models and data to improve air quality assessments for decision makers.</p> <p>Sponsoring agencies: NASA</p> <p>Observation type: field campaign</p> <p>Location: South Korea</p> <p>Timeline: May – June 2016</p> <p>More information: http://www-air.larc.nasa.gov/missions/korus-aq/</p>
<i>Layered Atlantic Smoke Interactions with Clouds (LASIC)</i>	<p>Description: LASIC is a deployment of the DOE Atmospheric Radiation Measurement Mobile Facility and Mobile Aerosol Observing System to Ascension Island to study how smoke from biomass burning in Southern Africa is transported across the Atlantic, how the aerosol properties change during transport and aging, and the aerosol effects on low clouds. LASIC will advance fundamental understanding of the physical and chemical processes associated with biomass burning aerosols, their interactions with clouds, and their impact on the Earth's energy budget.</p> <p>Sponsoring agencies: DOE</p> <p>Observation type: field campaign</p> <p>Location: Ascension Island</p> <p>Timeline: June 2016 – October 2017</p> <p>More information: http://www.arm.gov/campaigns/amf2016lasic</p>
<i>Megacities Carbon Project</i>	<p>Description: the Megacities Carbon Project aims to demonstrate a scientifically robust capability to measure multi-year emission trends of carbon dioxide, methane, and carbon monoxide attributed to individual megacities and selected major sectors. Studies over Los Angeles and Paris, as well as planning for a study over São Paulo, are underway.</p> <p>Sponsoring agencies: NASA, National Institute of Standards and Technology, Keck Institute for Space Studies</p> <p>Observation type: surface measurement network</p> <p>Location: Los Angeles, Paris</p> <p>Timeline: August 2015 (current network installation complete) – present</p> <p>More information: https://megacities.jpl.nasa.gov/portal/</p>
<i>North Atlantic Aerosols and Marine Ecosystems Study (NAAMES)</i>	<p>Description: NAAMES is a five-year investigation to resolve key processes controlling ocean system function, their influences on atmospheric aerosols and clouds, and their implications for climate. Observations obtained during four targeted ship and aircraft measurement campaigns, combined with the continuous satellite and <i>in situ</i> ocean sensor records, will enable improved predictive capabilities of Earth system processes and will inform ocean management and assessment of ecosystem change.</p> <p>Sponsoring agencies: NASA</p> <p>Observation type: field campaign, satellite, <i>in situ</i> ocean sensors</p> <p>Location: North Atlantic Ocean</p> <p>Timeline: January 2015 – January 2020</p> <p>More information: http://naames.larc.nasa.gov</p>

<p>Next Generation Ecosystem Experiment (NGEE)-Tropics</p>	<p>Description: NGEE-Tropics is a combined observational-modeling project to increase scientific understanding of how tropical forest ecosystems will respond to climate and atmospheric change, reduce uncertainty in Earth System Model projections, and discover if tropical forests will act as net carbon sinks through the 21st century. NGEE uses will couple observations and field campaigns in tropical forest regions with development of a process-rich tropical forest ecosystem model at a resolution better than 10 km.</p> <p>Sponsoring agencies: DOE, Smithsonian Tropical Research Institute, USDA Forest Service, NASA</p> <p>Observation type: field campaign</p> <p>Location: Puerto Rico; Manaus, Brazil</p> <p>Timeline: 2016–2026</p> <p>More information: http://esd1.lbl.gov/research/projects/ngee_tropics/index.html</p>
<p>Oceans Melting Greenland (OMG)</p>	<p>Description: OMG is a five-year mission using the Glacier and Ice Surface Topography Interferometer (GLISTIN) to generate high resolution, high-precision elevation measurements of Greenland’s coastal glaciers during boreal spring. Annual aircraft surveys measure glacier thinning and retreat over the preceding season, and a second aircraft campaign each year deploys 250 temperature and salinity probes along the continental shelf to measure the volume and extent of warm, salty Atlantic water. This data, along with fundamental new and critical observations of airborne marine gravity and ship-based observations of the sea floor geometry will provide a revolutionary data set for modeling ocean/ice interactions and lead to improved estimates of global sea-level rise.</p> <p>Sponsoring agencies: NASA</p> <p>Observation type: field campaign</p> <p>Location: Greenland</p> <p>Timeline: July 2015 – July 2020</p> <p>More information: https://omg.jpl.nasa.gov/portal/</p>
<p>ObseRvations of Aerosols above Clouds and their intEractions (ORACLES)</p>	<p>Description: ORACLES is a five-year investigation designed to study key processes that determine the climate impacts of aerosols from biomass burning in Africa. ORACLES provides multi-year airborne observations over the complete vertical column of the key parameters that drive aerosol-cloud interactions in the Southeast Atlantic, an area with some of the largest inter-model differences in aerosol forcing assessments on the planet.</p> <p>Sponsoring agencies: NASA (EVS-2)</p> <p>Observation type: field campaign</p> <p>Location: Southeast Atlantic Ocean</p> <p>Timeline: February 2015 – February 2020</p> <p>More information: http://science.nasa.gov/missions/oracles/</p>
<p>O₂/N₂ Ratio and CO₂ Airborne Southern Ocean (ORCAS)</p>	<p>Description: ORCAS is an airborne field campaign to advance understanding of the physical and biological controls on air-sea exchange of oxygen and carbon dioxide in the Southern Ocean, through intensive airborne surveys of atmospheric oxygen, carbon dioxide, related gases, and ocean surface properties over biogeochemical regions adjacent to the southern tip of South America and the Antarctic Peninsula.</p> <p>Sponsoring agencies: NSF, NASA</p> <p>Observation type: field campaign</p> <p>Location: Puntas Arenas, Chile</p> <p>Timeline: January – February 2016</p> <p>More information: https://www.eol.ucar.edu/field_projects/orcas</p>
<p>Olympic Mountains Experiment (OLYMPEX)</p>	<p>Description: OLYMPEX is a ground and airborne field campaign designed to verify and validate satellite measurement of precipitation from the constellation of satellites known as the Global Precipitation Measurement (GPM). The primary goal is to validate rain and snow measurements over the Olympic Peninsula in Washington State, and to determine how remotely sensed GPM measurements can be applied to a range of hydrologic, weather forecasting, and climate data.</p> <p>Sponsoring agencies: NASA</p> <p>Observation type: field campaign</p> <p>Location: Washington</p> <p>Timeline: November 2015–February 2016</p> <p>More information: http://olympex.atmos.washington.edu</p>

Ozone sonde Mini Campaign	<p>Description: the Ozone sonde Mini Campaign involves dual flights in Boulder, Fiji (February 2015), and dual flights in Samoa and Fiji (August 2015) conducted to determine the vertical difference in ozone profiles when different types of chemical solution are used to prepare ozone sondes, with the intent of homogenizing ozone sonde time series at 10 NOAA-operated sites.</p> <p>Sponsoring agencies: NOAA</p> <p>Observation type: field campaign</p> <p>Location: Fiji, Samoa</p> <p>Timeline: February 2015 – August 2015</p> <p>More information: http://igaco-o3.fmi.fi/VDO/files/Harris_ozone_trends_initiative.pdf</p>
Plains Elevated Convection at Night (PECAN)	<p>Description: PECAN is a field campaign to obtain targeted observations in critical locations before and during nighttime severe storms, with a key focus on the atmospheric layer between 500-1000 meters above the ground, in order to learn how these storms form, why some become severe, and how to better predict their characteristics in weather and climate models.</p> <p>Sponsoring agencies: NSF, NASA, NOAA, DOE</p> <p>Observation type: field campaign</p> <p>Location: Kansas, Oklahoma, and Nebraska, United States</p> <p>Timeline: June–July 2015</p> <p>More information: http://www.pecan15.org/home/</p>
Salinity Processes in the Upper Ocean Regional Study 2 (SPURS-2)	<p>Description: SPURS-1 and SPURS-2 are a pair of oceanographic field experiments addressing the essential role of the ocean in the global water cycle studying salinity changes that span thousands of miles together with those happening in the top centimeter of the ocean. The overall goal of SPURS-2 is to improve understanding of the physical processes that influence upper-ocean salinity and sea surface salinity in a precipitation-dominated regime with net freshwater and buoyancy fluxes into the ocean.</p> <p>Sponsoring agencies: NASA, NSF, NOAA</p> <p>Observation type: field campaign</p> <p>Location: eastern tropical Pacific Ocean</p> <p>Timeline: August 2016–August 2017</p> <p>More information: http://ourocean3.jpl.nasa.gov/spurs2/index.php</p>
Soil Moisture Active Passive (SMAP)	<p>Description: SMAP is a satellite mission with the goal of providing a capability for global mapping of soil moisture and freeze/thaw state with unprecedented accuracy, resolution, and coverage. Science objectives are to understand processes that link the terrestrial water, energy and carbon cycles; estimate global water and energy fluxes at the land surface; quantify net carbon flux in boreal landscapes; enhance weather and climate forecast skill; and develop improved flood prediction and drought-monitoring capabilities. On July 7, 2015, SMAP's radar stopped transmitting, marking the end of soil moisture radar operations; however, the passive SMAP soil moisture radiometer continues to return data.</p> <p>Sponsoring agencies: NASA</p> <p>Observation type: satellite</p> <p>Location: global</p> <p>Timeline: January 2015–May 2018</p> <p>More information: http://smap.jpl.nasa.gov</p>
Soil Moisture Active Passive Validation Experiment 2015 (SMAPVEX15)	<p>Description: SMAP is a satellite mission with the goal of providing a capability for global mapping of soil moisture and freeze/thaw state with unprecedented accuracy, resolution, and coverage. Science objectives are to understand processes that link the terrestrial water, energy and carbon cycles; estimate global water and energy fluxes at the land surface; quantify net carbon flux in boreal landscapes; enhance weather and climate forecast skill; and develop improved flood prediction and drought-monitoring capabilities. On July 7, 2015, SMAP's radar stopped transmitting, marking the end of soil moisture radar operations; however, the passive SMAP soil moisture radiometer continues to return data.</p> <p>Sponsoring agencies: NASA</p> <p>Observation type: satellite</p> <p>Location: Arizona, United States</p> <p>Timeline: January 2015–May 2018</p> <p>More information: http://smap.jpl.nasa.gov</p>

<p>Shale Oil and Natural Gas NEXUS (SONGNEX)</p>	<p>Description: the SONGEX campaign aims to quantify the emissions of trace gases, fine particles, and methane from several types of oil and shale gas basins in the western United States at different stages of development, and to study the chemical transformation of these emissions.</p> <p>Sponsoring agencies: NOAA, NASA, NSF</p> <p>Observation type: field campaign</p> <p>Location: North Dakota, Wyoming, Utah, Colorado, Texas, and New Mexico</p> <p>Timeline: March–May 2015</p> <p>More information: http://www.esrl.noaa.gov/csd/projects/songnex/</p>
<p>SMAP Validation Experiment 2016 (SMAPVEX 16)</p>	<p>Description: The SMAPVEX-16 campaign flew an L-band radar and microwave radiometer over US and Canadian agricultural areas to further evaluate SMAP satellite data products.</p> <p>Sponsoring agencies: NASA, USDA, Agriculture Canada, Canadian Space Agency</p> <p>Observation Type: field campaign</p> <p>Location: Iowa and Manitoba.</p> <p>Timeline: June-August 2016</p> <p>More information: http://smap.jpl.nasa.gov/</p>
<p>Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE)</p>	<p>Description: the SPRUCE experiment, conducted in a black spruce peat bog in in the U.S. Forest Service Marcell Experimental Forest in northern Minnesota, tests mechanisms controlling the vulnerability of organisms, biogeochemical processes, and ecosystems to climate change. SPRUCE is focused on the combined responses to multiple levels of warming at ambient or elevated carbon dioxide levels, towards improving fundamental understanding and model representation of ecosystem processes under climate change.</p> <p>Sponsoring agencies: DOE, USDA-Forest Service, EPA</p> <p>Observation type: surface measurement</p> <p>Location: Minnesota, United States</p> <p>Timeline: 2015–2025</p> <p>More information: http://mnspruce.ornl.gov</p>
<p>Wind Forecast Improvement Project 2 (WFIP-2)</p>	<p>Description: WFIP-2 records surface solar radiation budget measurements in the Columbia River Gorge in Washington state. These measurements support forecast improvements for renewable energy application in foundational numerical weather prediction models built by NOAA.</p> <p>Sponsoring agencies: DOE, NOAA</p> <p>Observation type: field campaign</p> <p>Location: Columbia River Gorge, Washington</p> <p>Timeline: October 2015–March 2017</p> <p>More information: http://www.esrl.noaa.gov/psd/renewable_energy/wfip2/</p>
<p>Wintertime Investigation of Transport, Emissions, and Reactivity (WINTER)</p>	<p>Description: WINTER evaluates the atmospheric chemical transformations and transport associated with anthropogenic emissions during winter in the mid-Atlantic region of the United States, including the Marcellus Pennsylvania shale play. Measurements will be made in large urban and industrial plumes, coal-fired power plant emission and distributed emissions from oil and gas extraction, agricultural or biofuel burning, and vegetation.</p> <p>Sponsoring agencies: NSF, NOAA</p> <p>Observation type: field campaign</p> <p>Location: Northeastern United States</p> <p>Timeline: February–March 2015</p> <p>More information: http://www.atmos.washington.edu/~thornton/field-campaigns/wintertime-investigation-transport-emissions-and-reactivity</p>

Appendix IV: Glossary

Adaptation

Adjustment in natural, human-natural, or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

Aerosol (atmospheric)

Fine solid or liquid particles, caused by people or occurring naturally, that are suspended in the atmosphere. Depending on their composition, aerosols can cause cooling by scattering incoming radiation or by affecting cloud cover, or cause warming by absorbing radiation.

Arctic tundra

A biome with cold, desert-like conditions, short growing seasons, low biotic diversity, and poor nutrients, located in the northern hemisphere. A layer of permanently frozen soil called permafrost exists below the surface. Alpine tundra also exists in high altitude regions throughout the world.

Atmospheric circulation

The large-scale movement of air, and together with ocean circulation, the means by which heat is distributed on the surface of the Earth.

Atmospheric rivers

Relatively narrow regions in the atmosphere that are responsible for most of the horizontal transport of water vapor outside of the tropics. Atmospheric rivers can create extreme rainfall and floods in some situations.

Baseline emissions

A measurement of greenhouse gas emissions at a given point in time, used as a basis for tracking emissions trends over time.

Biodiversity

The variety of life, including the number of plant and animal species, life forms, genetic types, habitats, and biomes (which are characteristic groupings of plant and animal species found in a particular climate).

Biogeochemical cycles:

Fluxes, or flows, of chemical elements among different parts of the Earth: from living to non-living, from atmo-

sphere to land to sea, from soils to plants.

Carbon cycle

The continuous flow of carbon atoms through atmosphere, oceans, soil, and living organisms as a result of photosynthetic conversion of carbon dioxide into complex organic compounds by plants, which are consumed by other organisms, and return of the carbon to the atmosphere as carbon dioxide as a result of respiration, decay of organisms, and combustion of fossil fuels.

Carbon dioxide

The primary greenhouse gas emitted through human activities. See also carbon cycle.

Carbon sequestration

The process of capturing carbon dioxide from the atmosphere, measured as a rate of carbon uptake per year.

Carbon stocks

The amount of carbon stored in an ecosystem, mainly in living biomass and soil, but also in decomposing organic materials. Stocks have the capacity to accumulate or release carbon.

Climate

The average of weather over at least a 30-year time period.

Climate change

Changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of the climate system.

Climate forecast

A probabilistic statement about future climate conditions on time scales ranging from seasons to decades, based on conditions that are known at present and assumptions about the physical processes that will determine future changes. "Climate prediction" is an equivalent term.

Climate model

A mathematical model for quantitatively describing, simulating, and analyzing the interactions between the atmosphere and the underlying surface (e.g., ocean, land, and ice)

Climate prediction

See climate forecast.

Climate projection

A long-term estimation of climate conditions produced by a climate model, usually forced by atmospheric greenhouse gas concentrations.

Climate variability

Natural changes in climate that fall within the observed range of extremes for a particular region, as measured by temperature, precipitation, and frequency of events. Drivers of climate variability include the El Niño Southern Oscillation and other phenomena.

Convection

The transfer of heat through a fluid by the movement of the heated material. Convective motions in the atmosphere are responsible for the redistribution of heat from the warm equatorial regions to higher latitudes and from the Earth's surface upward.

Coupled models

Climate or Earth system models that allow different components of the system to interact with and influence one another; for instance, a coupled ocean-atmosphere model.

Drought

A period of abnormally dry weather marked by little or no rain that lasts long enough to cause water shortage for people and natural systems.

Earth system

Earth's interacting physical, chemical, and biological processes.

Earth System Models

Numerical representations of the interactions among the atmosphere, ocean, land, ice, biosphere, and human activities to estimate the state of regional and global climate under a wide variety of conditions.

Ecosystem

All the living things in a particular area as well as components of the physical environment with which they interact, such as air, soil, water, and sunlight.

Ecosystem services

The benefits produced by ecosystems on which people depend, including, for example, fisheries, drinking water, fertile soils for growing crops, climate regulation, and aesthetic and cultural value.

El Niño/Southern Oscillation (ENSO)

Natural variability of sea surface temperatures and the air pressure of the overlying atmosphere in the tropical Pacific Ocean. The warm phase of ENSO, El Niño, is associated with high surface air pressure in the western tropical Pacific and warm sea surface temperatures in the eastern tropical Pacific, while the cold phase, La Niña, is associated with low surface air pressure in the western tropical Pacific and cool sea surface temperatures in the eastern tropical Pacific. Each phase generally lasts for 6 to 18 months. ENSO events occur irregularly, roughly every 3 to 7 years. The extremes of this climate pattern's oscillations can cause extreme weather (such as floods and droughts) in many regions of the world.

Ensemble Forecast

Multiple predictions from an ensemble of slightly different initial conditions and/or various versions of models. The objective is to improve the accuracy of the forecast through averaging the various forecasts, which eliminates non-predictable components, and to provide reliable information on forecast uncertainties from the diversity amongst ensemble members. Forecasters use this tool to measure the likelihood of a forecast.

Extratropical

In meteorology and climate science, the area north of the Tropic of Cancer and the area south of the Tropic of Capricorn. In other words, the area outside of the tropics.

Extreme events

A weather event that is rare at a particular place and time of the year, including, for example, heat waves, cold waves, heavy rains, periods of drought and flood-

ing, and severe storms. Extreme events are often associated with significant economic damages.

Feedback

The phenomenon through which a process or system is controlled, changed, or modulated in response to its own output. Positive feedback results in amplification of the system output; negative feedback reduces the output of a system.

Food security

When all people at all times have both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life.

Forcing

A factor that affects the Earth's climate, either in the short- or long-term; examples include natural factors such as volcanoes, and human factors, such as the release of heat-trapping gases and particles through fossil fuel combustion.

Global change

Planetary-scale changes to atmospheric circulation, ocean circulation, climate, the carbon cycle, the nitrogen cycle, the water cycle and other cycles, biological diversity, food webs, health, fish stocks, changes in sea ice and sea level, pollution, and more. Civilization is now a large driver of global change so the term includes population, the economy, resource use, energy, development, transport, communication, land use and land cover change, urbanization, and globalization.

Global warming

The observed increase in average temperature near the Earth's surface and in the lowest layer of the atmosphere. In common usage, "global warming" often refers to the warming that has occurred as a result of increased emissions of greenhouse gases from human activities. Global warming is a type of climate change; it can also lead to other changes in climate conditions, such as changes in precipitation patterns.

Global Climate Models

Mathematical models that simulate the physics, chemistry, and biology that influence the global climate system.

Greenhouse gases

Gases that absorb heat in the atmosphere near the Earth's surface, preventing it from escaping into space. This 'greenhouse effect' occurs naturally; an increase in the effect in response to a higher concentration of the atmospheric concentrations of these gases rise, the average temperature of the lower atmosphere will gradually increase, a phenomenon known as the 'enhanced greenhouse effect.' Greenhouse gases include, for example, carbon dioxide, water vapor, and methane.

Heat wave

A period of abnormally hot weather lasting days to weeks.

Hydrography

The measurements and description of the physical features of oceans, seas, coastal areas, lakes and rivers.

Ice sheet

A mass of glacial ice covering surrounding terrain, also known as a continental glacier. The only current ice sheets are in Antarctica and Greenland.

In situ

A sensor situated in the location of the measurement it is taking, as opposed to a remote sensor, which takes measurements from a distance.

Integrated Assessment Modeling

A systems analysis-based approach to environmental assessment that is capable of simulating both the drivers and consequences of environmental change, often within an economic or risk-based framework.

Indicator

An observation or calculation that allows scientists, analysts, decision makers, and others to track environmental conditions and trends, understand key factors that influence the environment, and assess risks and vulnerabilities.

Interannual variability

Year-to-year variability in climate conditions.

Intraseasonal variability

Variability in climate conditions on timescales (ranging from a few days to more than a month) within a season.

Irradiance

Radiated energy emitted from a body, such as the sun.

Land cover

The physical characteristics of the land surface, such as crops, trees, or pavement.

Land use

Activities taking place on land, such as growing food, cutting trees, or building cities.

Methane

A colorless, odorless greenhouse gas with a wide distribution in nature. After carbon dioxide, it is the most prevalent greenhouse gas emitted by human activities. In the first two decades after its release, its heat-trapping potential is 84 times more potent than carbon dioxide.

Mitigation

Measures to reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing carbon dioxide from the atmosphere.

Mixing ratio

The ratio of the mass of an atmospheric constituent to the mass of dry air.

Observations

Systematic collection of primary source data that describes the state of a system.

Ocean acidification

The process by which ocean waters have become more acidic due to the absorption of human-produced carbon dioxide, which interacts with ocean water to form carbonic acid and lower the ocean's pH. Acidity reduces the capacity of key plankton species and shelled animals to form and maintain shells.

Ozone

An inorganic molecule found in the atmosphere that is damaging to plant and animal tissue at higher concentrations. The ozone layer in the upper atmosphere prevents damaging ultraviolet light from reaching the Earth's surface. Ozone is also a greenhouse gas.

Peatland

An area with or without vegetation with a naturally accumulated layer of high-carbon, partially decomposed plant material that has accumulated in a water-saturated environment and in the absence of oxygen. The warmer the climate, the more quickly the plant material will decompose.

Permafrost

Ground that remains at or below freezing for at least two consecutive years.

Preparedness

Actions taken to build, apply, and sustain the capabilities necessary to prevent, protect against, and ameliorate negative effects. See also definition in Executive Order 13653.

Process research

Study of the underlying mechanisms controlling the components of the Earth system.

Remote sensing

The science of obtaining information about objects or areas from a distance, by detecting the energy that is reflected from the Earth's surface via sensors usually mounted on satellites or aircraft.

Representative Concentration Pathways

Descriptions of a range of potential futures for the main drivers of climate change: greenhouse gas emissions and land use, spanning high emissions scenarios to a low scenario consistent with the aim of limiting the increase of global mean temperature to less than 2 degrees Celsius.

Resilience

Capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

Risk

Threats to life, health and safety, the environment, economic well-being, and other things of value. Risks are often evaluated in terms of how likely they are to occur (probability) and the damages that would result if they did happen (consequences).

Risk management

Planning to manage the effects of climate change to increase positive impacts and decrease negative impacts.

Salinity

Salt content of a liquid. Salinity impacts the density of water masses, and has a significant impact on ocean circulation.

Scenario

Sets of assumptions used to help understand potential future conditions such as population growth, land use, and sea-level rise. Scenarios are neither predictions nor forecasts. Scenarios are commonly used for planning purposes.

Shared Socioeconomic Pathways

Quantitative and qualitative descriptions of plausible alternative solutions of society at the global level, to be combined with assumptions about climate change and policy responses to evaluate climate change impacts, adaptation, and mitigation.

Sink

A natural or technological reservoir that stores carbon from the atmosphere and stores it.

Spectroscopy

The study of the interaction between matter and electromagnetic radiation.

Stakeholder

An individual or group that is directly or indirectly affected by or interested in the outcomes of decisions.

Stressor

Something that has an effect on people and on natural, managed, and socio-economic systems.

Teleconnections

Large-scale climate anomalies that influence the variability of the atmospheric circulation, and have impacts on weather and climate patterns in different parts of the globe. For example, there appears to be a teleconnection between the tropics and North America during El Niño events.

Tipping point

The point at which a change in the climate triggers a significant environmental event, which may be permanent on human time scales, such as the melting and collapse of very large ice sheets.

Uncertainty

An expression of the degree to which future conditions (such as climate) are unknown. Uncertainty about the future climate arises from the complexity of the climate system and the ability of models to represent it, as well as the inability to predict the decisions that society will make. There is also uncertainty about how climate change, in combination with other stressors, will affect people and natural systems.

Validate

To establish or verify accuracy. In reference to remote sensing, validation involves using ground-based measurements to determine the accuracy of satellite data.

Vector

An organism, such as a mosquito, capable of transmitting disease.

Vulnerability

The degree to which physical, biological, and socio-economic systems are susceptible to and unable to cope with adverse impacts of climate change.

Appendix V: Acronyms

ABOVE	Arctic-Boreal Vulnerability Experiment	CDI	Climate Data Initiative
ACAPEX/CalWater 2	Cloud Aerosol Precipitation Experiment	CENRS	Committee on Environment, Natural Resources, and Sustainability
ACME	ARM Airborne Carbon Measurements	CLEEN	Continuous Lower Energy, Emissions, and Noise program
ACT-America	Atmospheric Carbon and Transport America	CLIVAR	Climate Variability and Predictability
AFOSR	Air Force Office of Scientific Research	CMIP	Coupled Model Intercomparison Project
ARM	Atmospheric Radiation Measurement	CMIP5	Coupled Model Intercomparison Project Phase 5
ARO	Army Research Office	COP	Conference of Parties to the United Nations Framework Convention on Climate Change
ARS	Agricultural Research Service		
ASTC	Association of Science-Technology Centers	COP21	21 st Conference of Parties to the United Nations Framework Convention on Climate Change
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer	CRREL	Cold Regions Research and Engineering Laboratory
ASTC	Association of Science-Technology Centers	CRT	Climate Resilience Toolkit
ATom	Atmospheric Tomography Mission	CYGNSS	Cyclone Global Navigation Satellite System
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer	DARPA	Defense Advanced Research Projects Agency
AWARE	ARM West Antarctic Radiation Experiment	DEWS	Drought Early Warning System
		DOC	Department of Commerce
CAAFI	Commercial Aviation Alternative Fuels Initiative	DOD	Department of Defense
CARVE	Carbon in Arctic Reservoirs Vulnerability Experiment	DOE	Department of Energy
		DOS	Department of State
CATS	Cloud-Aerosol Transport System	DOT	Department of Transportation
CDC	Centers for Disease Control and Prevention		

ECOSTRESS	ECOsysteM Spaceborne Thermal Radiometer Experiment on Space Station	GFDL-CM3	Geophysical Fluid Dynamics Laboratory Model Code 3
ENSO	El Niño/Southern Oscillation	GLISTIN	Glacier and Ice Surface Topography Interferometer
EPA	Environmental Protection Agency	GMB	Global Methane Budget
ERASMUS	Evaluation of Routine Measurements using Unmanned Aerial Systems	GO-SHIP	Global Ocean Ship-Based Hydrographic Investigations Program
ERDC	U.S. Army Corps of Engineers Engineer Research and Development Center	GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
ERS	Economic Research Service	GPM	Global Precipitation Measurement
ESM	Earth System Models	HHS	Department of Health and Human Services
FAA	Federal Aviation Administration	HMT	Hydrometeorology Testbed
FAC	Federal Advisory Committee	HyspIRI	Hyperspectral Infrared Imager
FEMA	Federal Emergency Management Agency	ICLUS	Integrated Climate and Land-Use Scenarios
FHWA	Federal Highway Administration	InFlux	Indianapolis Flux Experiment
FIA	Forest Inventory and Assessment	IPC	World Meteorological Organization International Pyr heliometer Comparison
ForestGEO	Smithsonian's Global Earth Observatories examining forests (formerly SIGEO)	IPCC	Intergovernmental Panel on Climate Change
FTA	Federal Transit Administration	IRI	International Research Institute for Climate and Society
GCB	Global Carbon Budget	IWG	Interagency Working Group
GCIS	Global Change Information System	JMS	Jamaican Meteorological Service
GCP	Global Carbon Project	KORUS-AQ/OC	Korea-United States joint field study on Air Quality/Ocean Color
GCRA	Global Change Research Act of 1990	LASIC	Layered Atlantic Smoke Interactions with Clouds
GEDI	Global Ecosystem Dynamics Investigation Lidar	LTAR	Long-Term Agroecosystem Research
GEOSS	Group on Earth Observation System of Systems		

MarineGEO	Smithsonian's Global Earth Observatories examining coastal marine habitats	NIHHIS	National Integrated Heat Health Information System
MASTER	Moderate Resolution Imaging Spectroradiometer (MODIS)/ Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Airborne Simulator	NIST	National Institute of Standards and Technology
MIROC5	Fifth Model on Interdisciplinary Research on Climate	NMME	North American Multi-Model Ensemble
MODIS	Moderate Resolution Imaging Spectroradiometer	NOAA	National Oceanic and Atmospheric Administration
NAAMES	North Atlantic Aerosols and Marine Ecosystems Study	NRCS	Natural Resources Conservation Service
NASA	National Aeronautics and Space Administration	NRI	National Resources Inventory
NASA ER-2	NASA Earth Resources 2	NSA	North Slope of Alaska
NASA-JPL	NASA Jet Propulsion Laboratory	NSF	National Science Foundation
NASS	National Agricultural Statistics Service	NWS	National Weather Service
NCA	National Climate Assessment	OCO-2	Orbiting Carbon Observatory 2
NCA3	Third National Climate Assessment	OLYMPEX	Olympic Mountains Experiment
NCA4	Fourth National Climate Assessment	OMG	Oceans Melting Greenland
NCAnet	National Climate Assessment network of networks	ONR	Office of Naval Research
NCAR	National Center for Atmospheric Research	ORACLES	ObseRVations of Aerosols above CLouds and their intEractionS
NGEE Arctic	Next-Generation Ecosystem Experiments-Arctic	ORCAS	Oxygen/Nitrogen Ratio and Carbon Dioxide Airborne Southern Ocean Study
NIDIS	National Integrated Drought Information System	OSHA	Occupational Safety and Health Administration
NIFA	National Institute of Food and Agriculture	OSTP	White House Office of Science and Technology Policy
NIH	National Institutes of Health	PCAP	President's Climate Action Plan
		PCN	Permafrost Carbon Network
		PECAN	Plains Elevated Convection at Night
		RADEX	Radar Definition Experiment
		RCP	Representative Concentration Pathway

SCAN	Soil Climate Analysis Network	UNFCCC	United Nations Framework Convention on Climate Change
SERDP	Strategic Environmental Research and Development Program	USACE	United States Army Corps of Engineers
SFIP	Solar Forecast Improvement Project	USAID	United States Agency for International Development
SGCR	Subcommittee for Global Change Research	USDA	United States Department of Agriculture
SGP	Southern Great Plains	USDA-FS	United States Department of Agriculture-Forest Service
SI	Smithsonian Institute	USGCRP	United States Global Change Research Program
SMAP	Soil Moisture Active Passive	USGS	United States Geological Survey
SMAPVEX15	Soil Moisture Active Passive Validation Experiment 2015	WFIP-2	Wind Forecast Improvement Project 2
SNOTEL	Snowpack Telemetry	WINTER	Wintertime Investigation of Transport, Emissions, and Reactivity
SONGNEX 2015	Shale Oil and Natural Gas Nexus	WMO	World Meteorological Organization
SPRUCE	Spruce and Peatland Responses Under Climatic and Environmental Change		
SPURS-1	Salinity Processes in the Upper Ocean Regional Study 1		
SPURS-2	Salinity Processes in the Upper Ocean Regional Study 2		
SSCC	Social Sciences Coordinating Committee		
SSWSF	Snow Survey and Water Supply Forecasting program		
START	global change SysTem for Analysis, Research, and Training		
SURFRAD	Surface Radiation Network		
TFCC	the Navy's Task Force Climate Change		
TOPDOWN	Twin Otter Projects Defining Oil/gas Well emissioNs		
UN	United Nations		